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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:	)	
	:	Examiner: Michael B. Shingleton
THOMAS JOHNSON, ET AL.	)	
Application No.: 10/727,528	)	Group Art Unit: 2817
Filed: December 5, 2003	)	
For: REDUCED ARCHITECTURE FOR MULTIBRANCH FEEDFORWARD POWER AMPLIFIER LINEARIZERS	) :) :	June 2, 2004

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

RESPONSE

Sir:

In response to the Office Action of March 25, 2004, Applicants submit the following comments.

Claims 5-8 were rejected in the Office Action under 35 U.S.C. § 103(a) as allegedly being unpatentable over U.S. Patent 6,452,446 (the "Eisenberg patent") in view of U.S. Patent 6,640,110 (the "Shapira patent").

Applicants note that the Eisenburg patent issued on September 17, 2002, from a non-provisional application filed on December 20, 2001 (hereinafter the "Eisenberg non-provisional application"). Both these dates are subsequent to Applicants' effective filing dates of October 18, 2001 (the filing date of the parent application to this application) and June 28, 2001 (the filing date of the provisional application to which this and the parent application claim benefit of priority). The non-provisional Eisenberg application claims priority benefit of a provisional patent application 60/259,012 filed on December

29, 2000 (hereinafter the "provisional Eisenberg application," a copy of which is attached), which predates the earliest effective filing date of the present application. Accordingly, the Eisenberg patent may be prior art to the present application, under 35 U.S.C. § 102(e), *if and only if* the features relied upon in the obviousness rejection are described and supported by the Eisenberg provisional application.[1] *See* 35 U.S.C. § 119(e), § 112, first paragraph.

Applicants submit that the Eisenberg patent is not prior art, because the features relied upon in the obviousness rejection are neither described nor supported by (and thus not in compliance with Section 112, first paragraph) the minimal five-page disclosure of the Eisenberg provisional application. Fig. 2 of the Eisenberg patent, relied on to show a feed-forward amplifier which provides an alleged distortion cancellation of 35 dB, is not part of, nor supported by, the Eisenberg provisional application. In fact, Fig. 2 of the Eisenberg provisional application is substantially different from Fig. 2 of the Eisenberg patent: Fig. 2 of the provisional application lacks any description of a multicarrier RF input signal (as depicted by a carrier frequency pair 12 in Eisenberg patent Fig. 2); it lacks disclosure of the internal structure and functionality of the so-called "power minimization loops" and "performance minimization loops;" and it lacks numerous circuit components (e.g., splitter 23, vector modulator 25, power detectors 37 and 97, to name just a few). Moreover, the very brief description of provisional Fig. 2, at paragraphs 7 and 8 of the Eisenberg provisional application, does not cure the above deficiencies. Further, Applicants note that the 35 dB of distortion cancellation alleged in the Eisenberg patent to be achieved by its Fig. 2 circuit, and relied upon in the obviousness rejection, is not alleged in the Eisenberg provisional application.

1/ With this response, Applicants do not waive their rights to attempt to swear behind this reference at a later date.

For all these reasons, it would be quite clear to those skilled in the art that the circuit of Fig. 2 of the Eisenberg provisional application does not describe or enable the circuit of Fig. 2 of the Eisenberg patent relied upon in the obviousness rejection. Furthermore, because of the lack of specific circuitry/functionality in the circuit of Fig. 2 of the Eisenberg provisional application, one skilled in the art would not have been able to make and use the circuitry to independently verify that the alleged signal to distortion ratio could actually be achieved. Consequently, Applicants submit that the Eisenberg patent's effective filing date is not prior to the December 20, 2001 non-provisional application filing date. Thus, the Eisenberg patent does not constitute prior art to the present invention.

In addition, the Office Action states that the Eisenberg patent "is silent as to what type of communications system is employed," and "is silent on naming the bandwidth of the system." This is also true of the Eisenberg provisional application. The Office Action further contends that, "as exemplified by Shapira it is well known to employ the linearized power arrangement in a cellular communication arrangement that handles multi-carriers and employs a wide bandwidth that comprises at least the whole operator-allocated band." The Office Action continues: "One would have been motivated to make the modification so as to provide a single linearized power amplifier over the entire bandwidth or operator-allocated band of a communications system as suggested by Shapira."

As discussed above, unlike the Eisenberg patent, the Eisenberg provisional application does not teach or suggest a multi-carrier (wide-band) RF input, and thus would not have motivated one skilled in the art *at the time of the filing of the provisional application* to use Eisenberg's circuitry in a wide-band cellular communications system, allegedly exemplified by the Shapira patent. Again, no such motivation could have been provided at least until the December 20, 2001 non-provisional application filing, which is subsequent to the filing date of the present invention.

In summary, the Eisenberg patent is not prior art to the present application, and this its disclosure cannot be applied to reject the claims of the present application. Accordingly, Applicants respectfully request withdrawal of the sole obviousness rejection, and that the application be allowed to pass to issue.

On another note, Applicants respectfully request that the PTO-1449 forms submitted with the Information Disclosure Statements of January 31, 2004 and December 5, 2003 be initialed and returned to Applicants, indicating that the information disclosed therein has been considered.

Applicants' undersigned attorney may be reached in our New York office by telephone at (212) 218-2100. All correspondence should continue to be directed to our address given below.

Respectfully submitted,

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Improved ACT Pre-Distortion Linearized Power Amplifier

Steve Avis, John Eisenberg

Mucenieks et al (6,111,452) have patented a novel, high efficiency RF power amplifier linearization technique using a pair of matched power amplifiers arranged so that one power amplifier pre-distorts the other.

Our invention incorporates several key improvements to the Mucenieks patent that may be applied individually or in concert to substantially improve the linearity of the amplifier. Our invention also incorporates means of maintaining amplifier linearity over a wide range of supply voltage, temperature and input signal conditions.

The essence of the Mucenieks patent and several of its benefits are described in the following paragraph. In his patent, Mucenieks describes a circuit in which distortion is extracted using a carrier cancellation means very similar to that found in most conventional feed forward RF power amplifiers. The extracted distortion products so obtained, are adjusted in amplitude and phase and combined with an appropriately delayed sample of the input signal. The scaled input signal alone is applied to the main power amplifier. The composite of the input signal and distortion products extracted from the main amplifier are applied to an error amplifier, substantially identical to the main power amplifier. The amplitude of the input signal component of the composite driving the error amplifier is adjusted to be the same as the amplitude of the pure input signal driving the main amplifier. Thus the distortion due to the input signal components driving both the main and error amplifiers are essentially the same. However, the error amplifier is also is driven by the distortion products extracted from the main amplifier. The phase and amplitude of these distortion products are adjusted so that they not only cancel the distortion products generated by the input signals applied to the error amplifier, but also replace these distortion products with equal amplitude anti-phase replicas of these products. Thus the delayed output of the main amplifier and the undelayed output of the error amplifier contain equal phase and amplitude amplified input signals and equal amplitude anti-phase distortion products. These signals are then added, so that the amplified signals add and the distortion products cancel. Thus the resulting output of the system is an amplified version of the input signal, substantially free of distortion, even though both the main and error amplifiers contain distortion products at their outputs. Both the main and error amplifiers contribute essentially equal amounts of amplified signal power to the output of the system. Operating efficiency is better than that of a conventional feed forward amplifier because the entire error amplifier's output power appears at the output of the system. Muceniek's circuit is not a feed forward amplifier. It is, as he claims, a type of RF pre-distortion, that is very effective because the source of the energy used to pre-distort the error amplifier is generated by an identical (main) amplifier driven by essentially the same input signals as the error amplifier. The level of the distortion components of the energy driving the error amplifier is approximately 30 dB below the input signal component. Thus the dynamics of both amplifiers is controlled by the dominant input signal energy.

Mucenieks employs a simple open loop means of adjusting the amplitude of the input signal components driving the main and error amplifiers. In his design the attenuators which adjust the power delivered to the main and power amplifiers are slaved together and it is then assumed that the resulting output signal and distortion energy delivered by the main and error amplifiers will be the same. Substantial practical production experience with power amplifiers based upon the Mucenieks design has shown this not to be the case. A closed loop means of independently adjusting the amplitude of the amplified input signals so that they properly add in phase is required. A second independent means of adjusting the phase of the distortion products generated by the error amplifier so that they simultaneously cancel the distortion products generated by the main amplifier is also necessary. A suitable control system to steer both of

these loops is essenti... to maintain performance over various conditions of supply voltage and temperature.

Our invention incorporates a means of independently adjusting the amplitude and phase of the amplified input signals so that they add in phase at the output of the system. The invention also incorporates means of independently adjusting the amplitude and phase of distortion products generated by the error amplifier so that these products cancel the identical products generated by the main amplifier. Both signal addition adjustment and the distortion cancellation adjustment are maintained by closed control loops. The resulting power amplifier using these features is able to maintain more than 20 dB of distortion reduction over a wide range of supply voltage, temperature and different input signal characteristics.

The pre-distortion architecture described by Mucenieks is capable of suppressing the amplitude of distortion products generated by the amplifiers by 20 to 25 dB. Often this level of correction is not satisfactory in modern wireless systems. The linearity of either Mucenieks amplifier, or the improved closed loop version of it described above can be greatly improved by wrapping a feed forward loop around the pre-distortion architecture. The feed forward loop reduces the amplitude of the distortion products by up to another 30 dB. The addition of the feed forward loop permits an overall signal to distortion ratioof as much as 85 dBc to be achieved. Because the pre-distortion architecture is more efficient than a equivalent single loop feed forward power amplifier, the overall pre-distortion, feed forward system is several percent more efficient than a dual loop feed forward design with similar performance. This concept is another feature of our invention.

In summary our invention incorporates the following improvements to the Mucenieks architecture. The improvements do not change the basic operation of his design, but instead render it immune to changes in its operating environment. Additionally we introduce the concept of wrapping a feed forward loop around the Mucenieks architecture to obtain an efficient, extremely linear RF power amplifier.

Specifically, what we claim is:

1. An architecture as shown in Figure 1 which incorporates:

2. An independent means of adjusting the amplitude and phase of carrier power delivered to the error amplifier is provided. The carrier power at the output of the error amplifier are maintained at the same amplitude and phase as the delayed carrier power at the output of the main amplifier. The carrier power generated by both the main and error amplifiers is combined without appreciable loss in the four port combiner hybrid.

3. A sensitive means of controlling the carrier power balance by sensing the amplitude of energy lost in the combining process. A four port (quadrature) combining hybrid junction is used. If equal amplitude and quadrature phase signals are incident upon the input ports of the hybrid, all off the input power is delivered to the hybrid's output port. If a phase or amplitude imbalance exists, power is leaked to the isolated port of the hybrid. A logarithmic amplifier senses this power, and the information so obtained is used to control the phase and amplitude of carriers delivered to the error amplifier in a closed loop fashion.

4. An independent means of controlling the amplitude and phase of distortion energy delivered to the error amplifier is provided. The distortion amplitude and phase is adjusted so that it not only cancels the distortion energy generated by the carrier power passing through the error amplifier, but also generates new distortion products equal in amplitude and opposite in phase from the original error amplifier distortion.

These ne\ stortion products cancel the distortion ge...rated by the main amplifier when the two are added together in the four port combiner hybrid.

5. A piloted control loop is used to maintain cancellation of the distortion energy. A small pilot signal at an out of band frequency is inserted into the main amplifier signal path. Another small pilot at exactly the same frequency and differing in both phase and amplitude is inserted into the error amplifier signal path. These pilots are set up so that they cancel at the output of the combiner when optimum distortion cancellation is obtained. A pilot receiver is used to sense the pilot power present at the output of the system. The receiver's output is used to adjust the amplitude and phase of the distortion delivered to the input of the error amplifier so that pilot power and hence distortion is minimized at the output of the system.

6. The resulting closed loop system maintains cancellation of distortion products over a wide range of supply voltage, temperature and input signal number, types and levels.

7. The architecture shown in Figure 2 incorporates a feed forward loop that is wrapped around the improved Pre-distortion architecture. The addition of the feed forward loop permits the aggregate amplifier to deliver extremely high linearity. Carrier to distortion ratios as high as 85 dB are routinely achieved. Efficiency is significantly better than that which is typically seen in competitive dual loop feed forward power amplifiers. The concept of wrapping a feed forward loop around the amplifier described in the Mucenieks patent is the subject of a pending Spectrian application by Cova et al. We wish to extend that concept to feed forward correction applied to our improved pre-distortion architecture with the pre-distortion and feed forward distortion cancellation loops controlled as describrd in claim 8.

8. The aggregate pre-distortion feed forward amplifier shares the same pilot generator and pilot receiver circuits. These shared circuits are used to maintain loop two distortion cancellation in both the pre-distortion and feed forward sections of the amplifier. This results in a simplification in the design that reduces the amplifier's size, complexity and cost. A common digital signal processor executing essentially the same algorithm may be employed to control both the pre-distortion and feed forward distortion cancellation loops.

These improvements may be applied individually or in concert to the amplifier described by Mucenieks to improve its producibility, render it immune to changes in its operating environment and substantially increase its linearity.

ACT ARCHITECTURE

Steve Avis and John Eisenberg

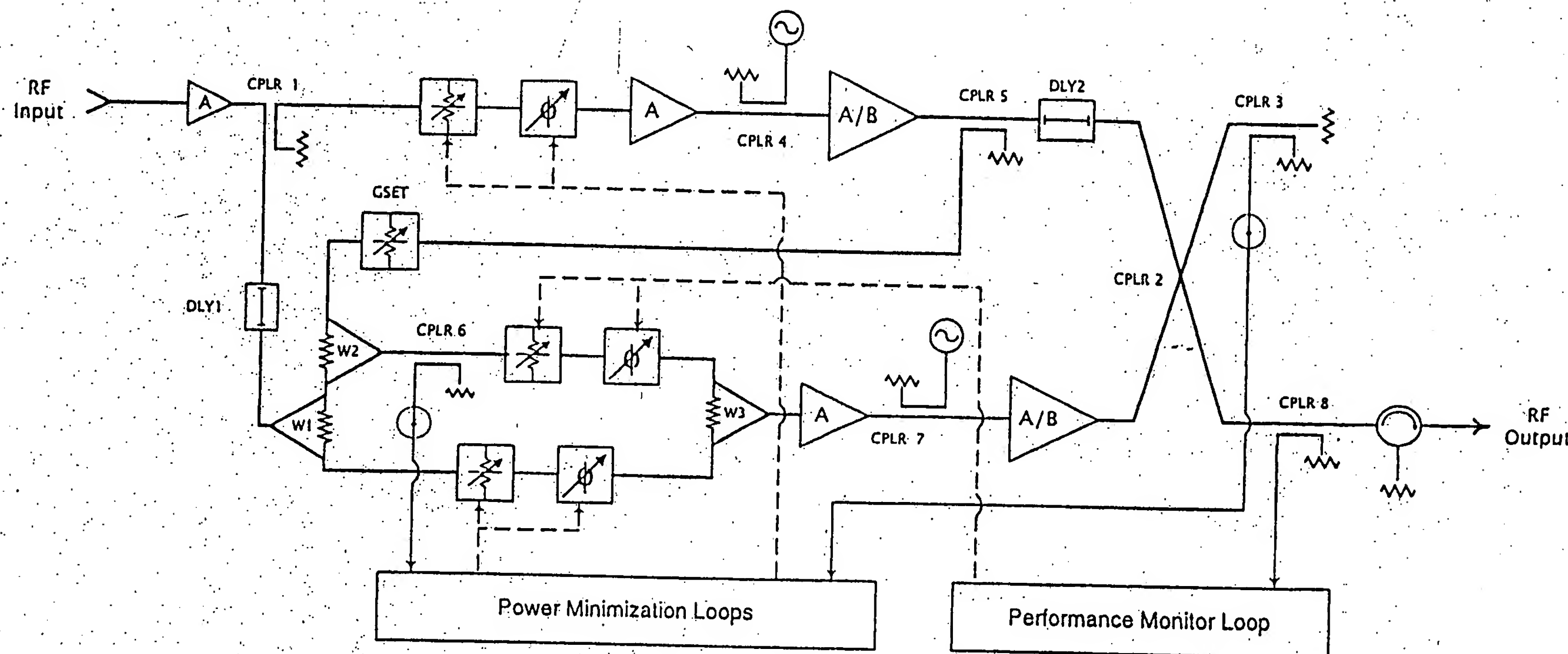

Figure 1.

ACT + FEEDFORWARD ARCHITECTURE

Steve Avis and John Eisenberg

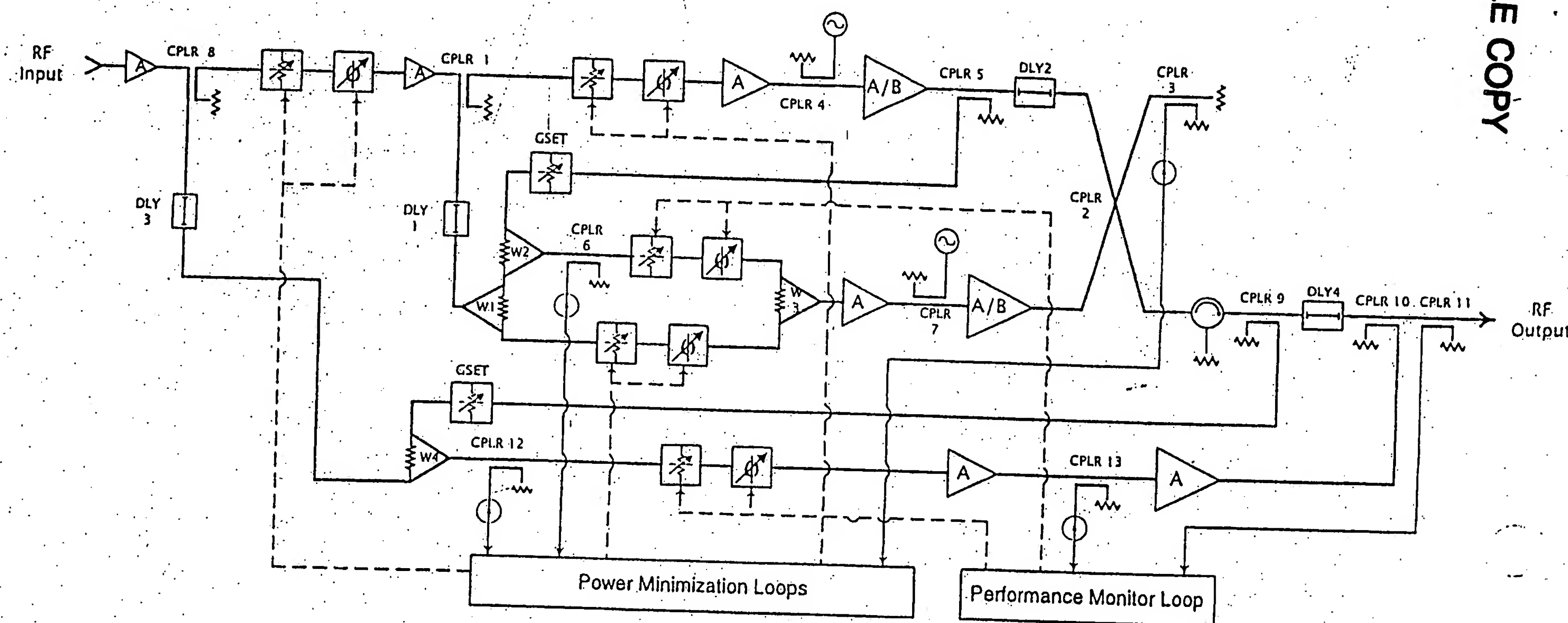

Figure 2.